

# Analyzing the Impact of Onsite Material Transportation on Time and Cost of the Building Construction Project Using Semi-Mechanized Equipment

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**Abstract**— Automation and Robotics plays a vital role in construction industries. In India, such automation technologies can't use at small scale construction projects because it is highly expensive. Where construction projects are described by short design and build period, increased demands of quality and low cost. These problems can be approached by using semi-mechanized equipment at small scale construction projects.

This work is undertaken to improve work efficiency of labourers working in small scale construction projects resulting in improved quality and reduction in project duration and cost. This semi-mechanized equipment (SME) can be used for lifting various on-site materials such as bricks, sand, cement bags, etc. In this report, the development and implementation of the semi-mechanized equipment is presented. Also a comparative study of SME with manual and SME with existing mini crane in the market is carried out for a defined unit task with respect to time, cost, net present value (NPV) and benefit cost ratio.

**Index Terms**— Semi-mechanized equipment, On-site material lifting, work efficiency, NPV

## 1 INTRODUCTION

Over the past few decades, improvements to productivity in the construction industry have been insignificant compared with other industries. The introduction of new technologies in the construction industry to fully automate the building process has been limited. The same is true for heavy/highway construction. The construction industry remains a skill-oriented and labour intensive industry with least automation of tasks.

The lack of automation in the construction industry can be credited to many factors. One of the problems to automating the construction process is the design of a project. That is, the design of a facility controls both; the use of available automated equipment during execution and the successful development of new automated equipment. In addition, the capabilities of automated equipment are constrained by the physical features of the design. Minor modifications to designs can potentially develop the use of automation and lead to increase construction productivity.

A competitive and market oriented tomorrow requires developing of automated construction system today. This includes construction material production, vertical & horizontal on-site transportation, on-site construction, prefabrication of components of construction, and treatment and recycling.

Today's construction projects are characterized by short design and build period, increased demands of quality and low cost. These problems can be approached by using SME at small scale construction sites. Especially, in high labour cost countries; mechanized construction technologies can compensate increasing demand on construction projects. The reduction of construction time would improve cost benefit analysis of construction project due to faster availability of equipment's.

Automated equipment's are highly expensive even operational and maintenance costs are high which is not affordable for small scale industries. Therefore, there is need to develop economical semi-mechanized equipment so that the small construction industries can able to purchase such equipment and use it to minimize the time and cost of project. It also helps to improve work efficiency of labourers by using SME method than that of manual method.

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## 2 DESIGN AND DEVELOPMENT OF SME

The equipment is designed and developed as SME. The equipment works on electrical supply. Even it is small in size and can be easily transported from one site to other site as it can be lifted by two to three persons. It is easy to operate the equipment and it can be operated by any, skilled or unskilled labour. But operating the equipment by skilled labour gives effective work than that of operating by unskilled labour.

The SME is developed to lift onsite materials. While designing the equipment some constrains are classified as discussed below:

- a) The rope used for lifting material is of 50 feet length; therefore, maximum height to lifting material is limited to 50 feet.
- b) The capacity of the equipment of lifting material at a time is 50 kg.

### 2.1 Design of semi-mechanized equipment

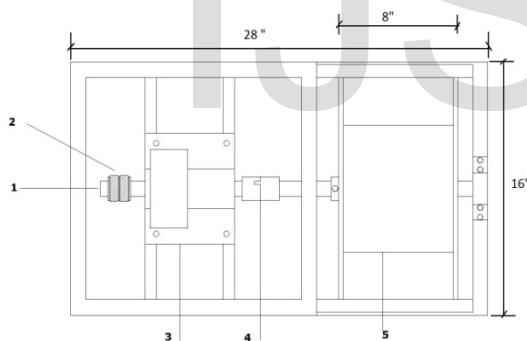


Figure 1 Plan of developed equipment

- 1=Shaft of an equipment of 1.2 inch diameter
- 2=Rubber belt connected to gear box and motor
- 3=Gear box
- 4=Coupler
- 5=Drum of 8 inch internal diameter

Motor of 1 Hp is mounted below gear box. The motor and gear box is conveyed by two rubber belts as shown in Figure No. 2. When power supply is switched on, motor starts rotating and makes to rotate the gear box by means of rubber belt, therefore, shaft starts rotating resulting to rotate the drum and rope is rolled on drum. Thus, the

material is lifted. Height of equipment is 23 inch. Arrangement of an SME during implementation is shown in Figure No. 3.



Figure 2 Developed semi-mechanized equipment

Motor specification: -

Geared motor with speed ratio of 43.  
Revolution = 1425 rpm  
Supply = 220 / 250 volts  
Power = 1Hp, Current = 65 amp

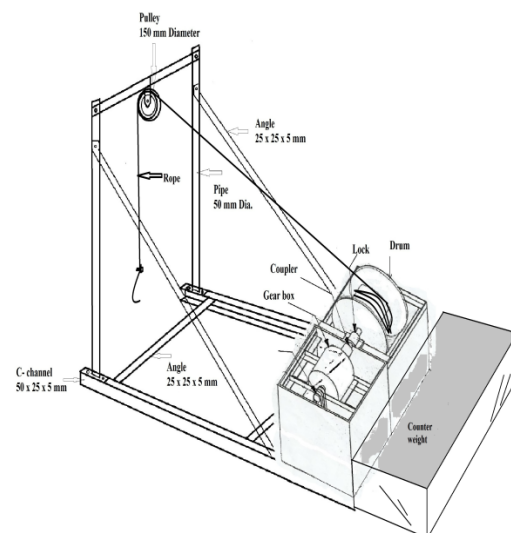


Figure 3. Arrangement of an equipment

### 3 RESEARCH DESIGN

In India, construction industries are labour intensive while big industries are machine as well as labour intensive. As small scale industries are not able to afford the machine costs and maintenances as it is highly expensive, therefore, they mainly depend on the manpower to be in field. Manual method is less efficient because it depends on work efficiency and skill of the workers. For this, five residential sites have being taken from Kolhapur, India. It observed that, what problems they are facing for lifting materials? Is there any need of mechanized equipment? How do they overcome with their problems? Keeping those problems in view, an attempt is made to develop SME to overcome the financial problem and labour problem of small construction industries. It is affordable to purchase by such small construction industries and can use for execution of work efficiently.

In small industries, manual lifting method is mostly preferred which is inefficient, time and cost consuming method. Therefore, to minimize these problems SME is developed. The developed equipment is less expensive as initial investment Rs 25,000/- and maintenance costs are low which will be economical for small construction industries. It is useful to improve the work efficiency and reduce unnecessary workers to save those payments which have to be paid for the workers. This material lifting method using SME shows good results by minimizing time and cost of the project.

### 4 COMPARATIVE STUDY & ANALYSIS OF MANUAL AND SME METHODS

In this, the data of time required for lifting the materials by manually as well as implementing the SME is collected from each residential construction site from Kolhapur, India. And the comparative study of both methods i.e. manually and SME is done to find out the impact on time and cost of the construction projects. For this purpose, five small residential sites are taken where the manually lifting method was used. From those sites, the materials such as bricks, cement and sand are taken to the working slab manually to execute the task. Time required to lift the materials is noted and calculated the total amount paid to the workers for the respective work. Then the manual lifting method is replaced by the SME method. By keep-

ing the quantity of material same as lifted by manual method, it was also lifted by equipment method and the time required for lifting the materials is noted and total amount required to do this work is calculated. After data collection from those five sites, comparative study of both the methods is done to find out the impact on time and costs of project.

**Site 1:** Data is collected from residential site 1 by implementing equipment on fourth floor for lifting materials required for execution of brickwork.

Table No. 1 Comparative study of manual and SME methods of site 1

Sr. No	Description	Manually	Semi-mechanized Equipment
1	Total number of workers	Male= 6 Female= 6	Male= 4 Female= 2
2	Number of days worked	3 days	1 ½ days
3	Total payment of workers	Rs 3000/-	Rs 1200/-
4	Other charges (electric bill+ rental+ installation)	-----	Rs 500/-
5	Work output		
	Bricks	2520 nos.	2520 nos.
	Sand	2.16 m <sup>3</sup>	2.16 m <sup>3</sup>
	Cement	2 bags	2 bags

From the comparative data of site 1, the effect on time and cost of the project is calculated. On this site, working hours are 09.00 am to 06.00 pm which means 09 hrs/ day. It is considered that, 9 hrs is equal to 1 day.

Sample calculation:

Time saved at Site = manually time consumed-  
time consumed by equipment method

$$= 3 - 1 \frac{1}{2} = 1 \frac{1}{2} \text{ days} = 50\% \text{ time saved}$$

Cost saved at Site = manually cost consumed- cost

consumed by equipment method

$$= 3000 - 1700 = \text{Rs } 1300/- = 43\% \text{ cost saved}$$

On this site, time and cost saved by implementing equipment method are 50% and 43% respectively.

**Site 2:** Data is collected from residential site -2 by implementing equipment on third floor for lifting materials required for execution of brickwork.

Table No. 2 Comparative study of manual and SME methods of site 2

Sr. No.	Description	Manually	Semi-mechanized Equipment
1	Total number of workers	Male= 10 Female= 6	Male= 4 Female= 2
2	Number of days worked	3 days	2 days
3	Total payment of workers	Rs 4500/-	Rs 1700/-
4	Other charges (electric bill+ rental+ installation)	-----	Rs 950/-
5	Work output		
	Bricks	5740 nos.	5740 nos.
	Sand	3.62 m <sup>3</sup>	3.62 m <sup>3</sup>
	Cement	---	---

From Site 2, it is observed that 1 day time and Rs 1850/- cost are saved by using SME lifting method. Even the labourer required for manual lifting method were 10 male and 6 female was working on site while for equipment method 4 male and 2 female were worked. Hence, it also reduces excess manpower.

On this site, working hours are 09.00 am to 06.00 pm which means 09 hrs/ day. It is considered that, 9 hrs is equal to 1 day.

**Site 3:** Data is collected from residential site 3 by implementing equipment on second floor for lifting materials required for execution of brickwork.

From the comparative data of site 3, the effect on time and cost of the project is calculated. On this site, working hours are 08.00 am to 06.00 pm which means 10 hrs/ day. It is considered that, 10 hrs is equal to 1 day.

Table No. 3 Comparative study of manual and SME methods of site 3

Sr. No.	Description	Manually	Semi-mechanized Equipment
1	Total number of workers	Male= 16 Female= - -	Male= 6.75 Female= --
2	Number of days worked	3 days	2 ¼ days
3	Total payment of workers	Rs 4800/-	Rs 2025/-
4	Other charges (electric bill+ rental+ installation)	-----	Rs 900/-
5	Work output		
	Bricks	5800 nos.	5800 nos.
	Sand	6.08 m <sup>3</sup>	6.08 m <sup>3</sup>
	Cement	--	2 bags

From this study, the calculations are made of Time and Cost saved of the projects by using SME. The time and cost of the project saved is calculated in terms of percentage as shown in Table No. 4.

Table no. 4 Impact on time and cost of the residential projects

Sr. No	Site name	Type of work	Working floor	Ts%	Cs %
1	Karpe building	Parapet Brickwork	4 <sup>th</sup> floor	50	43
2	Padmavti residency	Brickwork	3 <sup>rd</sup> floor	33	41
3	Padmavti residency	Brickwork	2 <sup>nd</sup> floor	25	39

\*Ts = time saved by equipment method

\*Cs = cost saved by equipment method

For 4<sup>th</sup> floor,

Time saved by equipment method= 50%

Cost saved by equipment method = 43%

For 3<sup>rd</sup> floor,

Time saved by equipment method = 41 %

Cost saved by equipment method = 33%

For 2<sup>nd</sup> floor,

Time saved by equipment method = 39%

Cost saved by equipment method = 25%

From the Table No. 4, the effect on time and cost saved by implementing the equipment on 2<sup>nd</sup> floor is 25% & 39% , while on 3<sup>rd</sup> floor 33% & 41% and implementing on 4<sup>th</sup> floor 50% & 43% respectively. Therefore, the savings of time and cost of the projects goes on increasing as the working floor increases.

From the data collection and comparative study, cost saved by semi-mechanized equipment method is calculated in terms of percentage. In this, cost saved per m<sup>3</sup> of sand to be lifted and cost saved per 1000 Nos. of bricks lifted on each selected construction site is shown in Table no. 5. The values obtained are different for a different site because the working floor and number of workers working on these sites were varies.

Table No. 5 Cost saved

Sr. No.	Working floor	Cost saved for lifting per 1000 Nos. of bricks (%)	Cost saved for lifting per 1 m <sup>3</sup> of sand (%)
1	4 <sup>th</sup>	47.50	47
2	3 <sup>rd</sup>	48	39
3	2 <sup>nd</sup>	45	25

## 5 NET PRESENT VALUE AND BENEFIT COST RATIO ANALYSIS FOR SITE 4

In small scale industry, the material has to be lifted manually which consumes much time, simultaneously affecting the work efficiency of workers. Instead of lifting materials manually, developed SME is used which is less expensive and economical.

This equipment was implemented on the residential site located at Sambhapur, near Pethvadgaon. On this site, three sets of readings of lifting the materials on working floor were collected by using both methods i.e. manual and semi-mechanized equipment methods. For collecting the readings, fixed quantities of materials were taken and compared the time required for lifting the materials by both methods as shown in Table No. 6. And calculated the total average amount paid for both the methods.

From comparative study, the cost saved by SME method is calculated. The analysis of net present value and benefit cost ratio for this construction project is calculated to know the feasibility of the project.

Payment of workers, Male= Rs 300/day

Female= Rs 200/day

Table No. 6 Data observation and comparative study of manual & SME lifting methods from site VI

Sr. No.	Worker		Material	Manual lifting method			Worker		Semi-mechanized method		
	M	F		4 June 13	5 June 13	6 June 13	M	F	10 June 13	11 June 13	12 June 13
1	2	3	BRICKS (No's)	1500	1500	1500	2	1	1500	1500	1500
2			SAND (m <sup>3</sup> )	1.06	1.06	1.06			1.06	1.06	1.06
3			CEMENT (Bags)	2	2	2			2	2	2
Time required (hrs) =				7	8	8.45			4	4.5	4.25
Amount (Rs) =				1200	1371	1448			960	1000	980
Average amount per day =				1340					980		

Therefore,

$$= \text{Rs } 9000 \text{ /-}$$

$$\text{Cost saved} = 1340 - 980$$

$$= 360 \text{ /- per day}$$

In this it is found that Rs 360/- per day are saved by using semi-mechanized equipment method.

Now cash flow is used to find out the net present value of the equipment.

**Cash flow:**

$$\text{Cost saved onsite} = \text{Rs } 360 \text{ /- per day.}$$

$$\text{Cost saved per month} = \text{Rs } 360 \times 25$$

Now consider that machine works for 10 months in a year,

Therefore,

$$\begin{aligned} \text{Annual profit gained} &= \text{Rs } 9000 \times 10 \\ &= \text{Rs } 90000 \text{ /-} \end{aligned}$$

$$\text{Initial investment} = \text{Rs } 25000 \text{ /-}$$

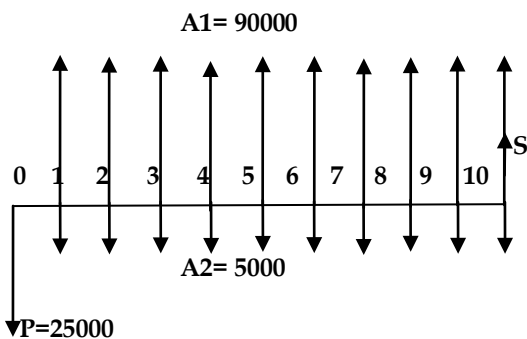
Assumed that,

$$\text{Life of the equipment (n)} = 10 \text{ years}$$

$$\text{Annual interest (i)} = 10\%$$

$$\text{Depreciation (j)} = 10\% \text{ per annum}$$

Annual maintenance and operating  
Cost = Rs 5000 /- per annum



So we have,

Net present value = cash inflow - cash out flow - depreciation

$$NPV = PV_1 - PV_2 - P_D - P$$

Where,

Depreciation by average annual investment method

$$D = \{P(n+1) + S(n-1)\} / 2n$$

$$\text{But, } S = P(1-j)^n = 25000(1-0.1)^{10} = 8716.96/-$$

$$D = \{25000 \times 11 + 8716.96 \times 9\} / 20 = 17672.63$$

Present value of depreciation,

$$P_D = D / (1+i)^n = 17672.63 / (1.1)^{10} = 6813.56$$

Therefore,

$$NPV = A_1 [(1+i)^{-n} - 1] / i(1+i)^{-n} + S / (1+i)^n - A_2 [(1+i)^{-n} - 1] / i(1+i)^{-n} - P_D - 25000$$

$$= 90000 [(1.1)^{-10} - 1] / 0.1(1.1)^{-10} + 8716.96 / (1.1)^{10} - 5000 [(1.1)^{-10} - 1] / 0.1(1.1)^{-10} - 6813.56 - 25000$$

$$= 553011.04 + 3360.76 - 30722.84 - 6813.56 - 25000$$

$$= \text{Rs } 493835.4/-$$

$$= \text{Rs } 494000 > 0 \text{ ---- (Ref. No. 7)}$$

Initial investment of SME is Rs 25000/- and cash inflow Rs 90000/- per annum, depreciation per annum is 10% and annual maintenance

costs is Rs 5000/-, then NPV of project for life of 10 years is Rs 494000/-. The equipment pays for itself just within one year.

Finally, Benefit cost ratio for this project is calculated below:

$$\text{Present value of benefits} = \text{Rs } 553011.04 + 3360.76/-$$

$$\text{Total costs} = \text{Rs } 25000 + 30722.84 + 6813.56$$

$$= \text{Rs } 62536.4 /-$$

Therefore,

$$\text{Benefit cost ratio} = \text{benefit} / \text{costs}$$

$$= 556371.8 / 62536.4$$

$$= 8.89 > 1$$

Benefit Cost ratio is the ratio of present value of cash inflow to the total costs. The calculated benefit cost ratio is 8.89 > 1; therefore, the project is beneficial.

## 6 COMPARISON AND ANALYSIS OF SEMI-MECHANIZED EQUIPMENT AND EXISTING EQUIPMENT IN MARKET I.E. MINI CRANE OR MINI LIFT

Mini crane is the equipment manufactured by a company was used for comparison. It was placed on the slab with 400 kg counter weight. It has a boom which swings between 0 - 180° angle for unloading the material on the slab.

This mini crane was evaluated for performance on the G+2 college building site at Gokul Shirgaon, Kolhapur. The work was going on the second floor of the building and crane was mounted on the first floor slab to lift the material. The photograph of the working mini crane on the site is shown in Figure No. 4.

Data was collected for lifting the materials on the working floor with respect to time. Following table no. 7 shows the tabulated comparative study of data collected of onsite material lifting using mini crane and SME.



Figure No. 4 Mini Crane

Cost economics of the comparative study:

Payment of workers at this site,

Male = Rs 300 /day                      Female = ---

Table No. 7 Comparative study of mini crane and developed SME

Sr. No.	Description	Mini crane	Semi-mechanized Equipment
1	Total number of workers	Male=4.5 Female= - -	Male= 6.25 Female= --
2	Number of days worked	1 ½ days	2 ¼ days
3	Total payment of workers	Rs 1350/-	Rs 1875/-
4	Rent charges of the equipment	Rs 1200/-	Rs 400/-
5	Other charges (electric bill+ installation)	Rs 200/-	Rs 150/-
6	Work output (A unit job)		

Bricks (Nos.)	5800	5800
Sand (m³)	6.10	6.10
Cement ( bags)	2	2

Total amount paid as per Table No. 7

Mini Crane (Rs) = 1350 + 1200 + 200

=2750 /-

SME (Rs) =1875 + 400 +150

=2425 /-

Therefore,

Net benefit = Amount paid for mini crane -

Amount paid for developed SME

= 2750 - 2425

= Rs 325/ one unit job

In this interpretation, even though the time required to complete one unit job by developed equipment is more than mini lift but Rs 342/- operational cost is saved by SME to execute the same quantity of work.

## 7 CONCLUSIONS

In this project, three residential sites are taken on which two lifting materials techniques i.e. manual and SME were carried out. Also with SME and Mini crane, data was collected separately and comparative study was done. From this study some conclusions are drawn below:

1. This equipment is developed as low cost semi-mechanized equipment with i.e. Rs 25000/-. It is economical and affordable for small scale construction project as compared with existing equipment (mini crane) cost of Rs 75000/-.
2. From the comparative study of data collected from three sites, resulting the effect on time and cost saved by implementing the equipment on 2<sup>nd</sup>



floor is 25% & 39% , while on 3<sup>rd</sup> floor 33% & 41% and implementing on 4<sup>th</sup> floor 50% & 43% respectively.

3. It is observed that, as the implementation of equipment on the working floor goes on increasing the savings of time and cost of the project too goes on increasing.

4. It helps to reduce the labour requirement on site.

5. From comparative analysis of site 4 data, it is concluded that semi-mechanized equipment lifting technique saves up to 26% daily cost than that manual method for the construction of G+2 storey building.

6. The calculated net present value is Rs 494000/- and benefit cost ratio 8.89. The equipment pays for itself just within one year.

7. When compared with mini crane in market the operational costs are less by 12%, for SME though the time required for completing the task (unit job) is more.

8. For the study work, the SME was implemented on selected construction sites for lifting the materials maximum up to the fourth floor. It is found that, as working floor were materials to be lifted goes on increasing the manual method consumes much time and cost as compared to SME method.

### 7.1 Advantages of the developed SME over existing equipments

1. Developed SME is less expensive with fabrication cost Rs 25,000/- than that of the mini crane cost Rs 75,000/-.

2. This equipment is having minimum carrying capacity 50 kg.

3. Existing Mini crane has to be disassembled and then assembled at working slab but the developed SME can be directly taken to the working slab without disassembling.

4. It requires less surrounding place than that of others.

5. Easily transported from one site to the other site.

6. No skilled operator is necessary to operate the equipment and reduces labour requirement on site.

7. The cost of SME is recovered just within one year almost three times the expenses of fabrication of SME.

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